



The Cross Section Viewer: A Tool for Automating Geomorphic Analysis Using Riverine Cross-Section Data

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PURPOSE: This U.S. Army Corps of Engineers (USACE) Regional Sediment Management Technical Note (RSM-TN) introduces the Cross Section Viewer, a software tool for storing, displaying, and automating common geomorphic analysis with riverine cross section data. This RSM-TN presents examples of three analyses that the Cross Section Viewer automates: (1) longitudinal profiles of average bed elevation, (2) longitudinal cumulative volume change curves, and (3) depth distributions.

INTRODUCTION: Bathymetric cross-sectional measurements have been the measurement standard on large rivers for decades. The federal government has spent hundreds of millions of dollars to collect these data that could, with effort, be used to generate important geomorphic information. However, these data often remain underutilized due to the lack of a standardized method for data storage and retrieval and because of the often labor-intensive nature of cross-sectional computations for large data sets. This RSM-TN describes the functionality of a software tool for storing, displaying, and automating common geomorphic analyses with riverine cross-section data. This tool was specifically developed for use on the Missouri River; however, the software has been made flexible for cross-section analysis on other rivers as well.

CROSS SECTION VIEWER: The USACE Kansas City District (NWK) partnered with North Arrow Research to develop the Cross Section Viewer, software which standardizes cross-section data storage and also facilitates data retrieval, display, manipulation, and the computation of geomorphic information. The underlying data are stored in a Microsoft Access database on the user's desktop or network drive. As the name suggests, the Cross Section Viewer allows easy viewing of cross-section data (Figure 1). Additionally, the software includes multiple import and export options, including import from and export to the USACE Hydrologic Engineering Center, River Analysis System (HEC-RAS), quality assurance/quality control tools, and benchmark adjustment tools. The database can store, and the software analyze, cross-section data in both English and metric units.

MISSOURI RIVER CROSS SECTION MONITORING PROGRAM: The Missouri River is a large, sand-bed river spanning 2,341 miles from the confluence with the Mississippi River at St. Louis, MO (Missouri River Mile [RM] 0), to the headwaters in southwest Montana. NWK is responsible for the lower 498 river miles, from the confluence with the Mississippi River at St. Louis, MO, to Rulo, NE (Missouri RM 498) (Figure 2).



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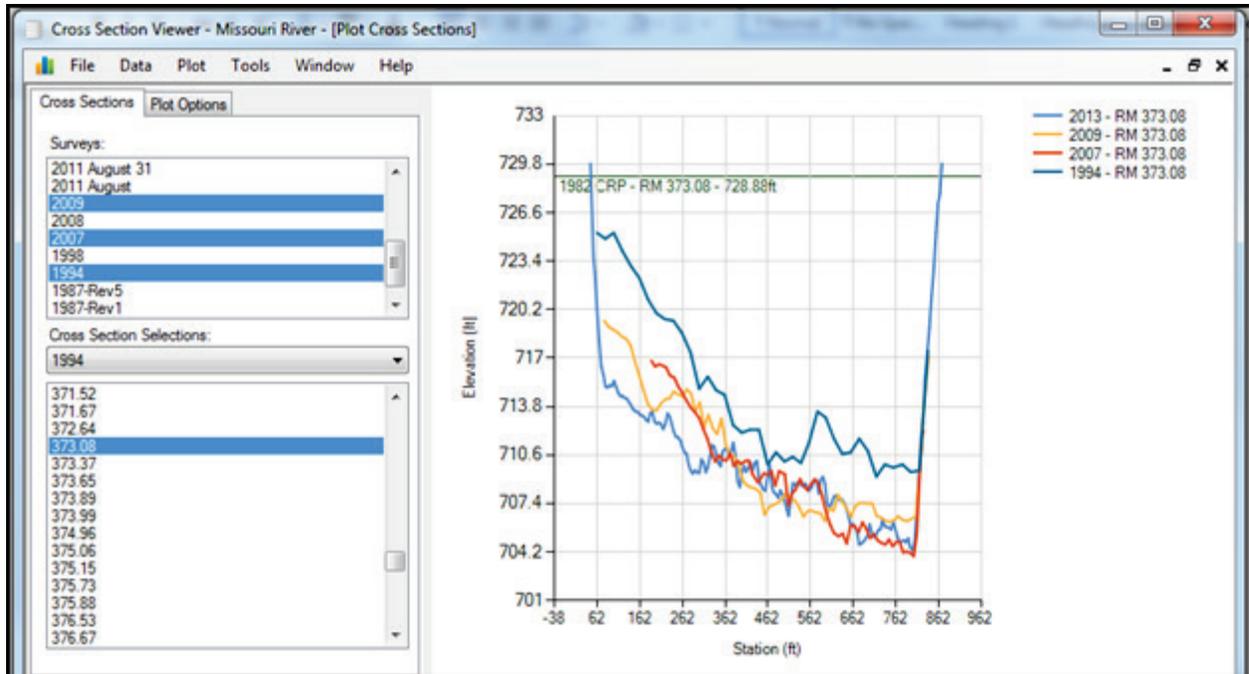


Figure 1. Plotting multiple years of survey data at a single location.

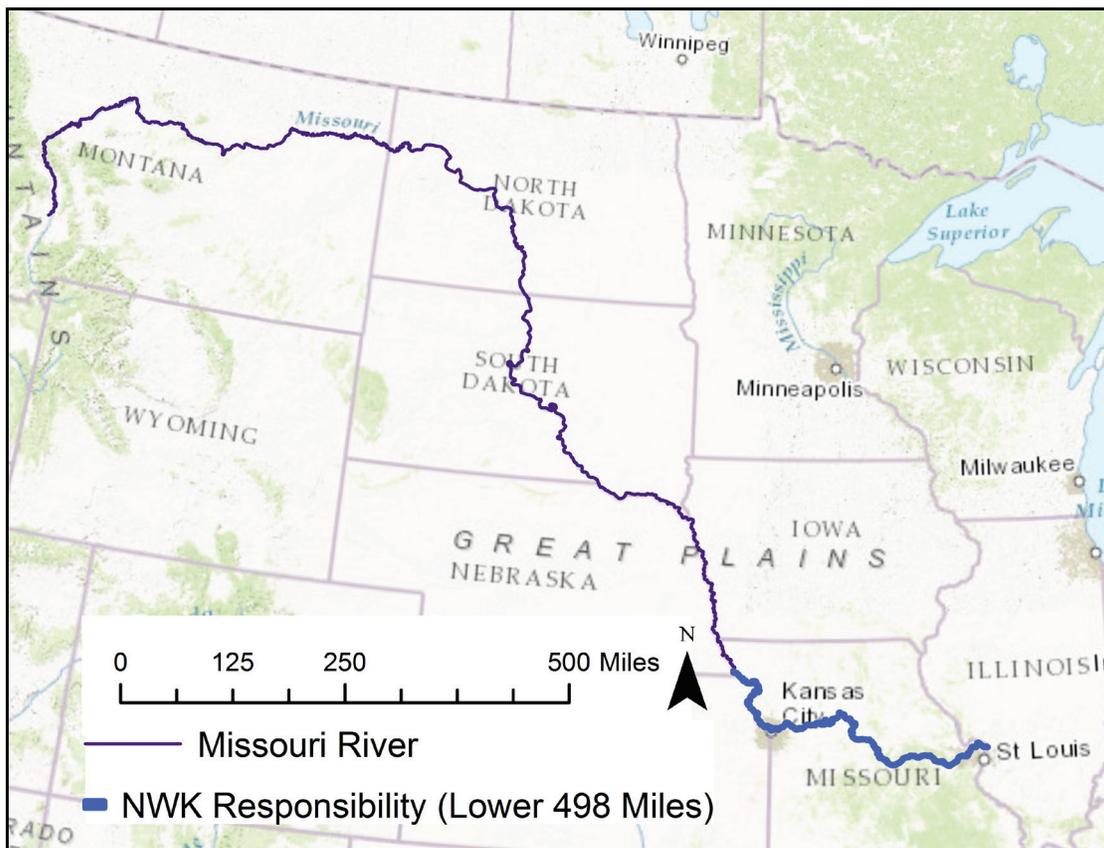


Figure 2. Missouri River overview map. Missouri RM 0 at confluence with the Mississippi River at St. Louis, MO. Background map source: ESRI (2017).



NWK has collected river bed elevation data on the Missouri River for decades. In 2007, concerns about bed degradation prompted the NWK to establish a consistent set of transect lines so that all future cross sections would be collected at coincident locations to allow tracking of bed changes. The 2007 survey included measured cross sections every 250 feet (ft) from RM 0 to 498 with denser cross sections at specific bends. This resulted in a data set of 11,706 cross sections. The survey was repeated in 2009, 2012, 2013, and 2014 at the same locations but not always with the same density. A river-wide bed survey from 1994 was later post-processed and those cross sections that coincided with a defined transect location were also analyzed. Table 1 lists the number of cross sections and average spacing for each of these surveys. Additional measurements with more limited geographic extent were collected in 2008 and 2011 but are not included in this RSM-TN.

Table 1. Number of cross sections surveyed each year.		
Survey Year	No. of Cross Sections	Average Spacing (ft)
1994	1,812	1,437
2007	11,706	250 (plus tighter spacing in a few bends)
2009	10,550	250
2012	1,302	2,020
2013	10,548	250
2014	5,263	500

Table 1 lists 41,181 cross sections since 1994, which represent over 7 million surveyed elevations. With effort, these data could be transformed into information on the locations of persistent high and low bed elevations, the volume of bed change over time, and the distribution of depths for habitat assessments. Computing useful information from such an extensive data set is a labor-intensive and cost-prohibitive task if attempted manually or by using existing tools. This RSM-TN demonstrates the functionality of the Cross-Section Viewer using this dataset.

EXAMPLE 1—LONGITUDINAL PROFILES OF AVERAGE BED ELEVATION:

Longitudinal profiles of average bed elevation provide an indication of how bed elevations change with regards to the longitudinal (i.e., upstream to downstream) direction. The river mile position of each cross section is plotted on the *x*-axis and a single representative elevation for each cross section on the *y*-axis. In many cases, the thalweg (deepest point of the cross section) elevation is selected as the representative elevation. While this simplifies the computations, on a sand-bed river such as the Missouri River, the thalweg is highly variable and not necessarily indicative of persistent geomorphic structure. The average bed elevation, while also subject to natural variability, provides a more stable representative elevation than the thalweg. Computation of the average bed elevation can be time intensive when done manually for a large number of cross sections. The Cross Section Viewer performs the following steps to facilitate this analysis:

1. Compute the cross-sectional area up to the maximum elevation in the cross section.
2. Divide the cross-sectional area by the top width (the last station minus the first station) to compute an average depth.
3. Subtract the average depth from the maximum elevation in the cross section to yield an average bed elevation.



The Cross Section Viewer computes the average bed elevation at each cross section. Figure 3 shows the results for RM 0 to 40 (plotted in Excel). As seen in Figure 3, locations of peaks and troughs in bed elevation persist from year to year. The peaks in average bed elevation correspond to bends, and the troughs correspond to crossings. Note that this is the opposite structure as would be expected in a thalweg survey.

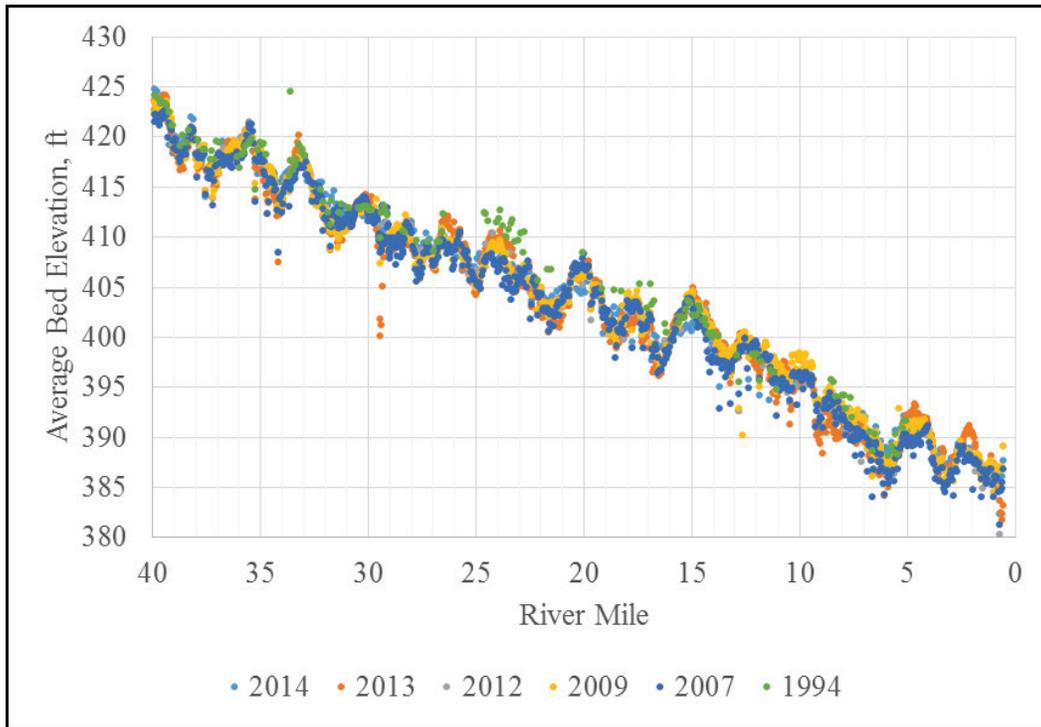


Figure 3. Average bed elevation of the Missouri River from RM 0 to 40, evidencing persistent peaks and troughs in bed elevation.

Figure 4 presents longitudinal profiles for RM 360 to 390, which encompasses the Kansas City metro area. As shown in Figure 4, this reach of the river has experienced significant degradation since 1994.

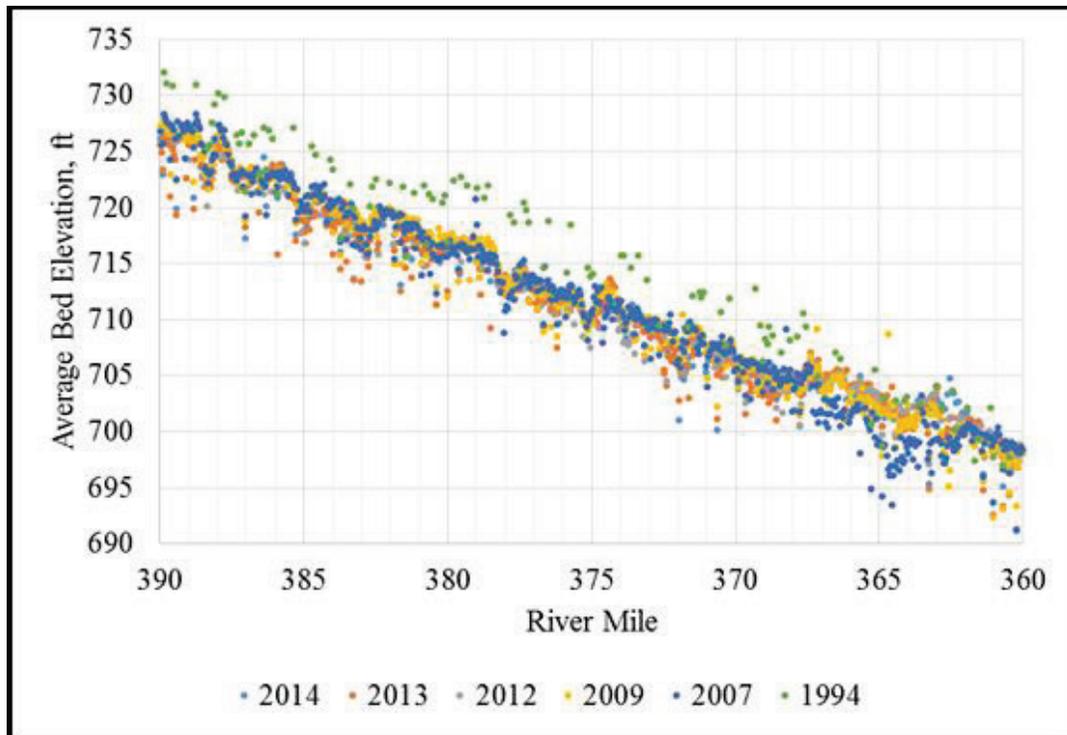


Figure 4. Average bed elevation of the Missouri River from RM 360 to 390, evidencing degradation since 1994.

EXAMPLE 2—LONGITUDINAL CUMULATIVE VOLUME CHANGE CURVES: Often, the absolute elevations are of less concern than the change in bed elevation over time. A longitudinal cumulative volume change computation integrates bed elevation changes over space, which dampens the noise of individual cross sections to depict trends. These curves are often used for calibrating sediment models. A correct calculation of volume change requires adherence to the following best practices: (1) Compare only similar locations along the river (i.e., cross sections should be at consistent locations from year to year). Figure 3 illustrated the importance of using consistent cross-section locations. If cross sections at peaks are included in one year and cross sections at troughs in another year, the analysis would compute spurious volume change. Creating a consistent set of cross sections requires removing from analysis any cross section that is not found in both surveys. (2) Compare only a similar lateral extent of the cross section in both years. The lateral extent of data collection on the Missouri River, and many other large rivers, varies by year depending on boat access on the day of survey. An apparently higher or lower bed elevation may be the result of one survey capturing more of the channel bank or point bar than another. For example, at RM 367.91 as shown in Figure 5, the 2013 survey would have a higher average bed elevation simply because it includes more of the channel banks. This best practice is employed by truncating the cross sections to a common lateral extent.



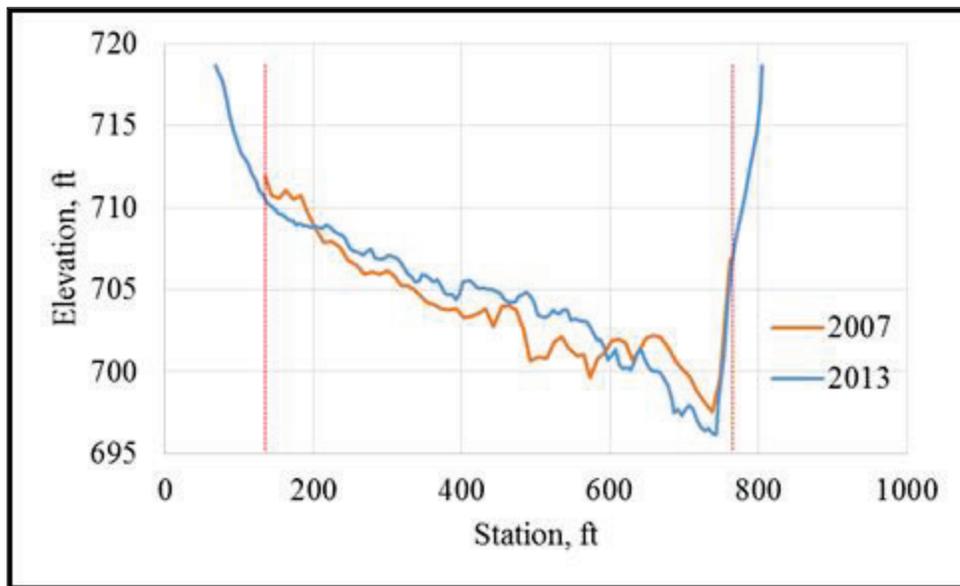


Figure 5. Different lateral extent in different years at Missouri River RM 367.91. Dotted lines represents limit of common extent of data.

Adherence to these best practices adds considerable time to a manual computation of volume change. The Cross Section Viewer automates this analysis by following these steps:

1. Determine coincident cross sections in two user-selected surveys.
2. Trim the cross sections to a common lateral extent or to a user-specified horizontal or vertical extent. Interpolate the end points as needed (almost always the case). For this analysis, only data present in both cross sections that fall within the Rectified Channel Lines was used.
3. Compute the cross-sectional area of each cross section up to a consistent vertical datum.
4. Subtract the cross-sectional areas to compute an area change at each cross section.
5. For each stretch of river bounded by an upstream and downstream cross section, multiply the average of the area changes at the bounding cross-section locations by the river distance between locations.
6. Sum the volume change in each control volume from upstream to downstream to create the longitudinal cumulative volume change.

Figure 6 plots longitudinal cumulative volume change curves computed with the Cross Section Viewer. The Cross Section Viewer can plot a single longitudinal cumulative volume change curve at a time. The data were exported and plotted in Excel to compare change over multiple time periods. Longitudinal cumulative volume change curves describe where and to what extent the bed changed between two surveys. An interpretation of the bed change history depicted in Figure 6 depends on additional information, which is not provided in this RSM-TN, such as the timing of major floods and the timing, quantity, and location of channel mining activities.

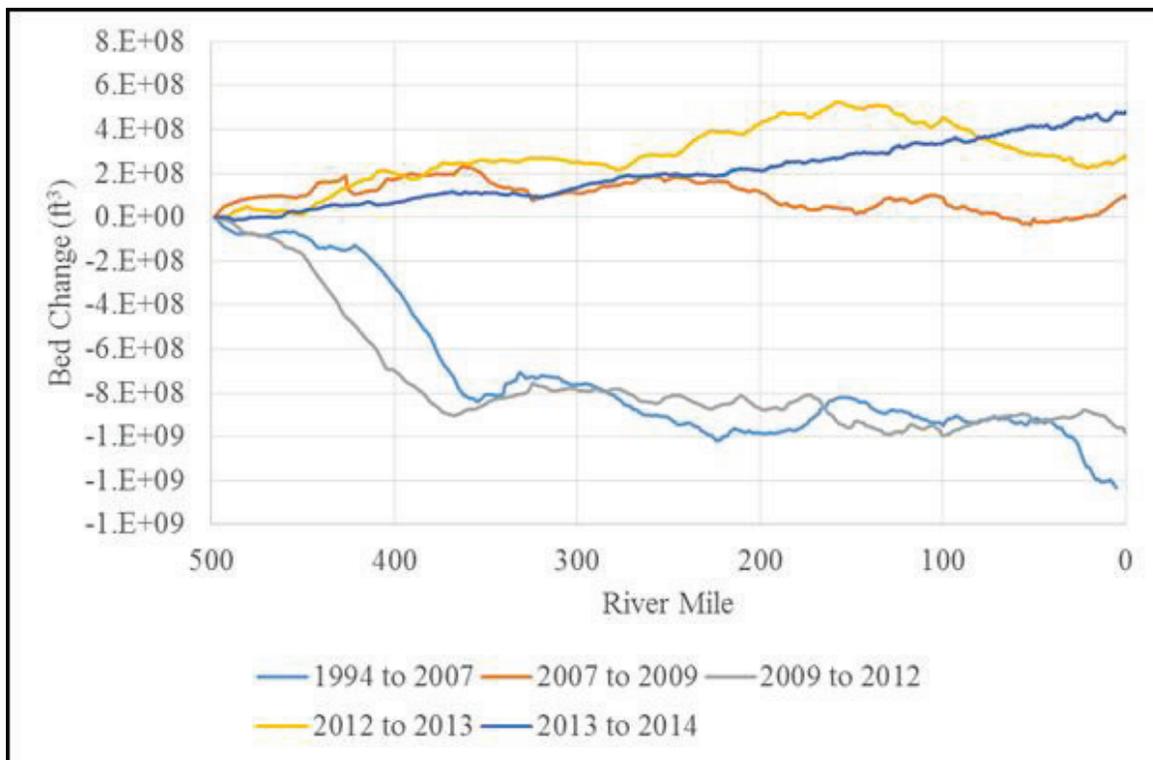


Figure 6. Longitudinal cumulative volume change curves on the Missouri River from RM 0 at St. Louis, MO, to RM 498 at Rulo, NE.

EXAMPLE 3–DEPTH DISTRIBUTIONS: Depth diversity plays an important role in aquatic habitat in many river systems. The Cross Section Viewer tool estimates the percentages and surface area totals corresponding to varying depths in the following manner:

1. At each cross section (Figure 7), the tool performs these steps:
 - a. Divide the cross section into slices of desired depth and compute the top width for each slice.
 - b. Subtract the width of each slice by the width of the slice above it to determine the width corresponding to only that depth.
2. For each segment of river bounded by an upstream and downstream cross section, multiply the average of the widths for a given depth at the bounding cross section locations by the river distance between cross-section locations. This is the planimetric area corresponding to that depth class for a single control volume.
3. Sum the planimetric area for each control volume to generate the total surface area corresponding to that depth class over user-defined RMs.
4. Divide by the total surface area to transform into a percentage.



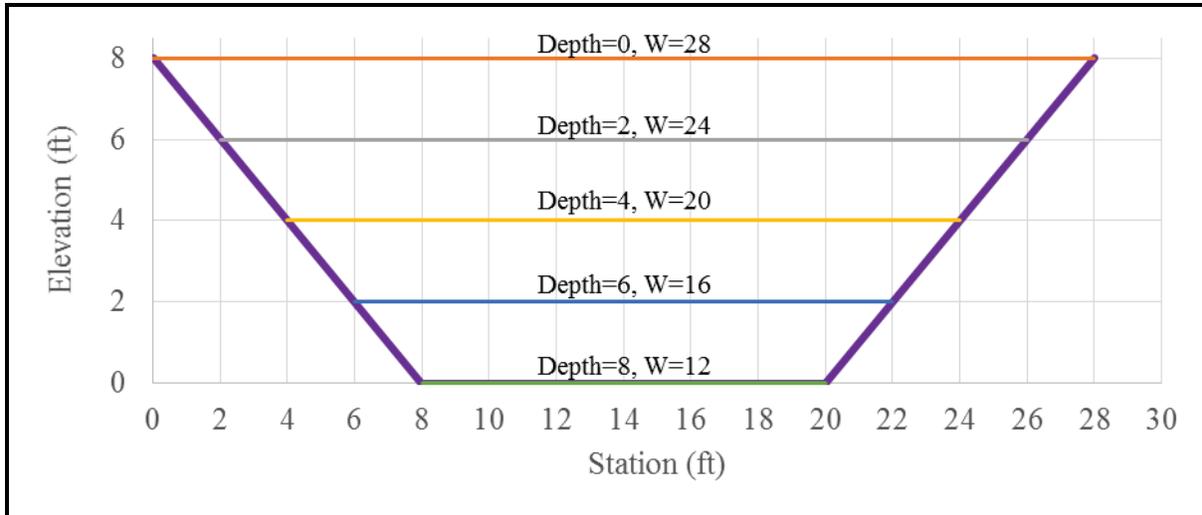


Figure 7. Example of procedure for computing depth distribution. In this example, the width of channel with a depth of 2 to 4 ft is (24 ft – 20 ft) = 4 ft.

The user specifies the elevation corresponding to depth 0. Through various functions in the software, this can be specified as an elevation at each cross section, a sloping plane with inflection points, an imported water surface from HEC-RAS, or as an offset from any of the above. Figure 8 provides distribution of depths in the Missouri River, relative to the 2010 Construction Reference Plane, for the 2014 survey.

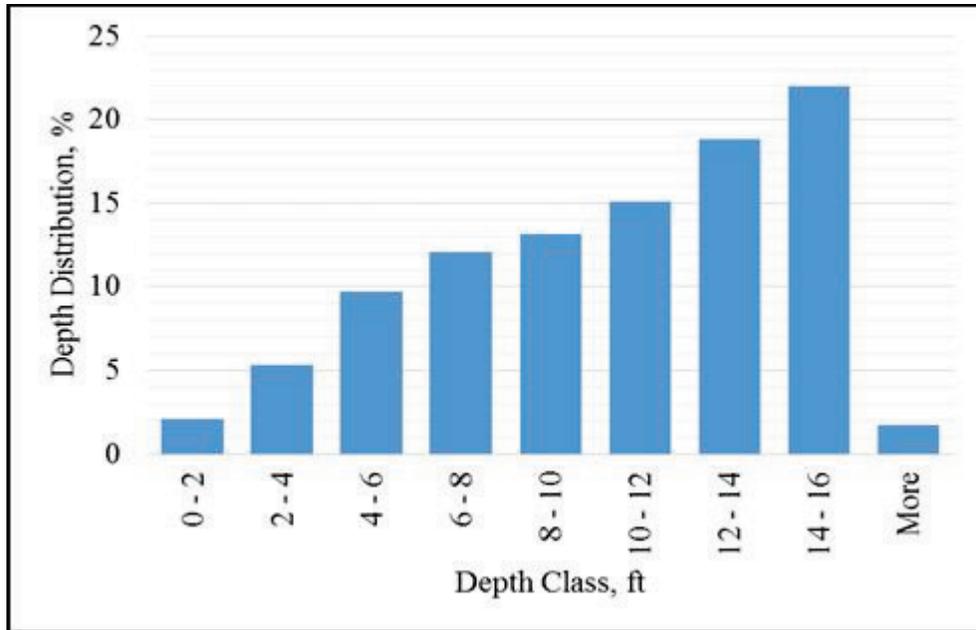


Figure 8. Depth distribution for 2014 bathymetric survey relative to the 2010 Construction Reference Plane.

FUNDING/DOWNLOAD: The software was developed using funding from a number of sources including the Missouri River Bank Stabilization and Navigation Project and the Missouri River Recovery Program.

The software, online help, and a users' manual are free to the public and are available at <http://xsviewer.northarrowresearch.com/>. The software comes with an empty database into which users can then import their cross-section data using several import templates.

CONCLUSION: The Cross Section Viewer software facilitates the storage, retrieval, and display of cross-section data and automates the computation geomorphic information. This RSM-TN showed the use of the software using a robust data set of cross sections collected on the Missouri River to compute (1) longitudinal profiles of average bed elevation, (2) longitudinal cumulative volume change curves, and (3) depth distributions. This software significantly increases the efficient use of cross-section data.

ADDITIONAL INFORMATION: This RSM-TN was prepared as part of the U.S. Army Corps of Engineers (USACE) National Regional Sediment Management (RSM) Program by John Shelley, USACE District, Kansas City (NWK). Additional information regarding the USACE National RSM Program can be found at the Regional Sediment Management website <http://rsm.usace.army.mil>.

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